ANALYSIS OF WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT (WEEE) IN THAILAND AND IMPLEMENTATION OF RISK MANAGEMENT PLAN TO COMPLY WITH FUTURE WEEE REGULATIONS

by

Jongsawas Chongwatpol

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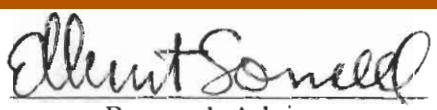

Research Advisor
Dr. Elbert Sorrell

The Graduate School

University of Wisconsin-Stout

September, 2004

The Graduate School

University of Wisconsin Stout

Menomonie, WI 54751

ABSTRACT

Chongwatpol	Jongsawas	-
(Writer) (Last Name)	(First Name)	(Middle Initial)

Analysis of waste electrical and electronic equipment (WEEE) in Thailand and implementation of risk management plan to comply with future WEEE regulations

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The current Thai regulations do not legislate the disposal of waste electrical and electronic equipment. Furthermore, the regulations do not require the producer to assume responsibilities for all costs involved in the disposal of these wastes. Lastly, there are no specific programs to take back the end-of-life product and no effective procedure for recovery, reuse or to recycle the product following the requirement of the European Union directives.

The purpose of the study was to develop a risk management program to address the disposal of waste from computers and computer components and to assist Thai companies in complying with the WEEE and RoSH directives.

The objectives of this study were:

1. To identify best practices to address waste from electrical and electronic equipment.
2. To identify possible redesign alternatives.
3. To develop risk management plan to address disposal of electrical and electronic waste to comply with the WEEE and RoSH legislation from European Union.

The methods and procedures included a review of literature pertaining to WEEE and RoHS directives and semi-unstructured interviews conducted with two companies that manufacture electrical and electronic equipment. The data gathered from the literature review and the interview conducted was analyzed in the following areas: (1) the arrangement, management, and awareness according to the legislation from European Union and United States, (2) the Extended Producer Responsibility (EPR) program regarding computer manufacturing, and (3) the disposal of electrical and electronic waste programs such as takeback, recycling, reuse and recovery program, and other disposals of electrical and electronic waste program. Four process maps were created to answer objectives of this study. These process maps included (1) redesign alternatives, (2) risk management plan, (3) end-of-life management, and (4) disposition of personal computer.

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CHAPTER I: INTRODUCTION

Electronic waste represents all waste from electrical and electronic components (WELSLAU, 1998). Categories of electrical and electronic equipment include large and small household appliances, information technology (IT), telecommunications equipment, consumer and lighting equipment, electrical and electronic tools, medical devices, monitoring and control instruments and automatic dispensers (WEEE, 2003).

Electrical and electronic equipment products are among the fastest growing industries in the world. Due to technological innovation and marketing expansion, new applications of electronic and electrical equipment and replacement processes are increasing rapidly (Lymberidi, 2001), resulting in an increase of electrical and electronic waste. Waste from electronic and electrical equipment (WEEE) is one of the largest known sources of toxic heavy metal and other pollutants, which contaminate the environment when not properly treated (Haugsten, 2002).

According to a report issued by the Green Design Initiative at Carnegie Mellon University, 50 million old computers are expected to be landfilled by 2005 and 143 million recycled computers will be landfilled. The magnitude of this issue creates many concerns within the European Union and the United States. Electronic waste represents less than 1% of waste generated in the Member State of European Union, three times the amount of waste generated from other municipal waste streams (Lymberidi, 2001) The Environmental Protection Agency estimates that computers and other electronic equipment will account for about 2 million tons of waste per year in the United States (Cnet, 2004). The volume of this waste problem cannot go unchecked.

Computer equipment is a primary source electronic waste. The lifespan of computer platforms is less than two years. After two years, computing equipment is essentially obsolete due to the dynamism of computer manufacturing and the speed of innovation. These rapid changes in advanced computer technology contribute to the electronic waste problem. A May 1999 report from *Electronic Product Recovery and Recycling Baseline Report* published by the well-respected National Safety Council's Environmental Health Center, confirmed that computer recycling in the United States is shockingly inadequate. In 1998, only 6% of computers were recycled compared to the numbers of new computers put on the market that year. Experts estimate there are over 315 million obsolete computers in the United States, many of which will be destined for landfills, incinerators or hazardous waste exports (Silicon Valley Toxics Coalition, 2004).

Approximately 90% of WEEE is landfilled, incinerated and recovered without pre-treatment (Silicon Valley Toxics Coalition, 2004). Appropriate treatment of electronic waste is needed in order to prevent hazardous substances from entering into the environment (Lymberidi, 2001). Processes are desperately needed to sufficiently curtail this emerging problem.

As a response to these concerns, the European Union Parliament established two directives known as Waste from Electrical and Electronic Equipment (WEEE) directive and Restriction of the use of certain Hazardous Substances (RoHS) directive (Eurochambres, 2000). The main objectives of these directives were to minimize and prevent generated waste, improve treatment of WEEE, restrict the use of hazardous substances, encourage reuse, recycle, and recover and remanufacture materials and energy used in various processes and to extend the manufacture responsibility. These

directives will have significant implications for many Asia countries and Thailand in particular.

The computer manufacturing industry is a major source of income for Thailand. The Thailand computer industry exports computers and computer components to the European Union and the United States. If Thailand expects to continue exporting computing equipment, it will be imperative to comply with the various electrical and electronic waste regulations promulgated by the European Union and the United States.

Currently, the regulations of disposal of electrical and electronic waste in Thailand are limited. There are no specific disposal regulations for waste from electrical and electronic equipment but there are regulations that are legislated for the disposal of hazardous waste and other waste streams. There is no legislation to provide guidance in the areas of reusing and recycling of electrical and electronic wastes. For the most part electrical and electronic wastes are disposed of as other general wastes.

Many Thai companies may lack the technological information related to electronic waste that will allow them to continue to export electrical and electronic equipment to the European Union and the United States. In addition, many companies are not prepared to deal the RoHS legislation (Electrical and Electronics Institute, 2003).

Statement of the Problem

The current Thai regulations do not legislate the disposal of waste electrical and electronic equipment. Furthermore, the regulations do not require that the producer assume responsibilities for all costs involved in the disposal of these wastes. Lastly, there are no specific programs to take back the end-of-life product and no effective procedure

for recovery, reuse or to recycle the product following the requirement of the European Union directives.

Purpose of the Study

The purpose of the study was to develop a risk management program to address the disposal of waste from computers and computer components and to assist Thai companies in complying with the WEEE and RoSH directives.

The objectives of this study were:

1. To identify best practices to address waste from electrical and electronic equipment.
2. To identify possible redesign alternatives.
3. To develop risk management plan to address disposal of electrical and electronic waste to comply with the WEEE and RoSH legislation from European Union.

Significance of the Study

The results of the study will be used as a guideline on best practices to handle waste from electrical and electronic equipment and provide redesign alternatives to protect human health and environment from the hazardous substances such as heavy metal contaminated in the product. Due to the European Union directive such as WEEE and RoSH legislation, it is the responsibility of the producer to take care of electronic wastes. Thus, this study would be helpful for other professionals to use the results and models as a guide to implement the risk management program in the process. This risk management program will consist of the takeback program, recovery, reuse, and recycle processes for the product following the requirement of the European Union directive.

Assumptions of the Study

Assumptions made for this study include:

1. Information presented in the literature that researcher reviewed and information gathered from the comparison companies were accurate
2. The process of manufacturing computer technologies and the disposing process of electrical and electronic equipment waste in Thailand are similar to the process of manufacturing computer technologies and the disposing process of electrical and electronic equipment waste in the United States. Therefore, the remediation procedure in the United States could be applied to Thailand.

Definition of Terms (WEEE, 2003 p.4)

Disposal: any of the applicable operations provided for in Annex II to Directive 75/442/EEC in Appendix A.

Producer: any manufacturer who produces and sells electrical and electronic equipment such as computer parts and components under his own brand, including any person who resells under his own brand equipment produced by other suppliers or any person who imports and exports electronic and electrical equipment.

Recovery: any of the applicable operations provided for in Annex II to Directive 75/442/EEC in Appendix A.

Recycling: the reprocessing in a production process of the waste materials for the original purpose or for other purposes, but excluding energy recovery which means the use of combustible waste as a means of generating energy through direct incineration with or without other waste but with recovery of the heat.

Reuse: any operation by which WEEE or components thereof are used for the same purpose for which they were conceived, including the continued use of the equipment or components thereof which are returned to collection points, distributors, recyclers or manufacturers.

Restriction of Hazardous Substances or RoSH: the directive that was established to limit the use of hazardous material such as lead, mercury, cadmium, hexavalent, chromium VI, PBB and PBDE in electrical and electronic equipment.

RoSH directive: the European Directive which forces the law on the restriction of the use of certain hazardous substances in the electrical and electronic waste, titled "Directive 2002/95/EC of the European Parliament and of Council of 27 January 2003;

Take back Program: the program which the manufacturer of electrical and electronic equipment takes back the end-of-life equipment for disposal;

Waste electrical and electronic equipment or WEEE: electrical or electronic equipment which is waste within the meaning of Article 1(a) of Directive 75/442/EEC, including all components, subassemblies and consumables which are part of the product at the time of discarding;

WEEE directive: the European Directive which forces the law on electrical and electronic waste, titled "Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003;

Limitations of the Study

The study is limited to the product and procedure from the computer industry in Thailand but using the information in the United States to solve the electronic waste problem in Thailand. This study used only the electronic waste from computer to be a case study.

CHAPTER II: LITERATURE REVIEW

Introduction

This chapter will discuss the WEEE and RoHS directives; current management of WEEE; hazardous materials in computer; recovery, recycle, remanufacturing and takeback program; eco-design and impact of WEEE and the proposed legislation in Thailand.

Hazardous Waste Regulation

The management of hazardous wastes and the cleanup of abandoned hazardous disposal is a major concern in the United States. Hazardous waste is defined as a solid waste material listed in Title 40 Code of Federal Regulations (CFR), Subpart C and D, part 261. Hazardous waste exhibits the characteristics of ignitability, corrosivity, toxicity and reactivity. The two major environmental regulations are the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). In addition, other environmental regulations deal with the management of air and water pollution such as the Clean Air Act (CAA), the Clean Water Act (CWA), and the Safe Drinking Water Act (SDWA) (Moore, 2000).

RCRA, administered by the Environmental Protection Agency (EPA), was passed in 1976 as an amendment to the Solid Waste Disposal Act (SWDA). RCRA appears on 40 CFR 260-281. Under this Act, the EPA has responsibility and authority to regulate hazardous waste. The major purposes of RCRA are to reduce and eliminate the generation of hazardous waste and to treat, store, and disposal of hazardous waste. It aims to minimize the present and future threat to public health and environment from improper

disposal of hazardous waste. It requires permit and a manifest system for the generation, storage, treatment, transportation and disposal of hazardous waste (EPA, n.d.). CERCLA was passed in 1980 as an amendment to the Superfund Amendments and Reauthorization Act (SARA). CERCLA regulation appeared in 40 CFR 300-302. The main purpose of CERCLA and SARA are to (1) provide remedial action at abandoned hazardous waste disposal site, (2) provide removal of spills of hazardous substance, (3) provide reporting releases to the environment of hazardous substances, and (4) provide natural resource damage assessments (Moore, 2000).

In the United States, the RCRA and CERCLA prohibits the disposal of hazardous waste including electronic waste products such as computer monitors in landfills. Failure to comply with these regulations may result in substantial fines and penalties. A violation of the hazardous waste control regulation is a crime and may be prosecuted (EPA, n.d.).

WEEE and RoHS Directives

Similar to RCRA and CERCLA, the European Union developed the WEEE and RoHS directives to address problems associated with the disposal of electronic waste. The European Union (EU) is the organization whose member states include United Kingdom, Italy, Belgium, France, Spain, Portugal, Luxembourg, Finland, Sweden, Germany, the Netherlands, Austria, Greece, and Denmark (European Communities, 2000). European Parliament is the principle deliberative and supervisory institution of the European Union (International Law Dictionary & Directory. 2003), which has power to adopt legislation called "directives" (European). These directives are directly applicable in all member states (European Communities, 2000).

The European Parliament and the council of the European Union established the WEEE directive to address problems associated with the disposal of electronic waste (WEEE, 2003). Producer responsibility for the management of WEEE is the main component of the directive. The producers are responsible for improving environmental quality of products and decreasing the quantity of electronic waste (EuroCommerce, 2001). The European Parliament has taken the lead on reducing WEEE by making producers responsible for taking back their products. This is known as Extended Producer Responsibility (EPR) (Silicon Valley Toxics Coalition, 2004).

The purpose of EPR is to reduce and prevent waste, increase re-use of WEEE and components, increase recovery and recycling of WEEE, and improve the environmental performance of procedures involved in the life cycle of electrical and electronic equipment. This can be accomplished by encouraging eco-design, product end-of-life management, life cycle thinking, and producer responsibility (Department for Environment Food and Rural Affairs, 2003). The producers are financially responsible for the impact of their whole-life-cycle products on the environment. This includes the cost of waste management, collection, treatment, recovery and safe disposal of products at the product end-of-life (European Environment Bureau, 1998).

As a response to these concerns, the European Union Parliament established two directives known as Waste from Electrical and Electronic Equipment (WEEE) directive and Restriction of the use of certain Hazardous Substances (RoHS) directive (WEEE 2003).

The purpose of WEEE directive is to prevent electrical and electronic waste and to reduce the disposal of waste by reusing, recycling and other forms of recovery.

Furthermore, the main objective of this directive is to improve the environmental performance of producers including operators, distributors and consumers, and to extend the producer responsibility to be involved in the treatment of electrical and electronic waste (Eurochambres, 2000). This directive applies to all electrical and electronic equipment under the categories indicated in Appendix A.

The WEEE directive requires producers to provide appropriate measures to collect and separate the waste components. It requires customers to return WEEE free of charge and requires producers to take back their product. Producers are required to pay for all costs related to the WEEE, which arises in the commercial and industrial stream. Producers must provide treatment of WEEE according to the standard and promote recovery and recycling of WEEE (WEEE, 2003).

All member states must ensure that all separately collected WEEE transported to treatment facilities is authorized under Article 6 of WEEE directives. Article 6 of WEEE outlines the standard of treatment facilities. Any establishment or undertaking carrying out treatment operations must obtain a permit from the competent authorities. Producers are financially responsible for the collection, treatment, recovery or disposal of WEEE (WEEE, 2003).

The Restriction of Hazardous Substances (RoHS) directive is a companion to WEEE directive. The European Parliament and the council of the European Union established RoHS directive to limit the use of hazardous substances in electrical and electronic equipment and to reduce the waste management problems involved with heavy metal and flame-retardants.

The objectives of this directive are to ensure harmonization of legislation to control hazardous substances in electrical and electronic equipment. In addition, this directive aims to limit the environmental impact of the end-of-life product of electrical and electronic equipment through the minimization of the use of hazardous substances. Starting July 1, 2006, member states must ensure that new electrical and electronic equipment do not contain lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls (PBB) or ply brominated dipheny ethers (PBDE). The RoHS directive contains an annex, which provides a list of exempted uses of these prohibited substances. Some substituted substances are not available or not feasible for substitutes (RoHS, 2003).

Electronic equipment, especially personal computers, contains large amounts of contaminants, including lead, mercury, cadmium, plastics, hexavalent Chromium (Chromium VI), and PVC. Figure1 represents the typical composition of electronic scrap.

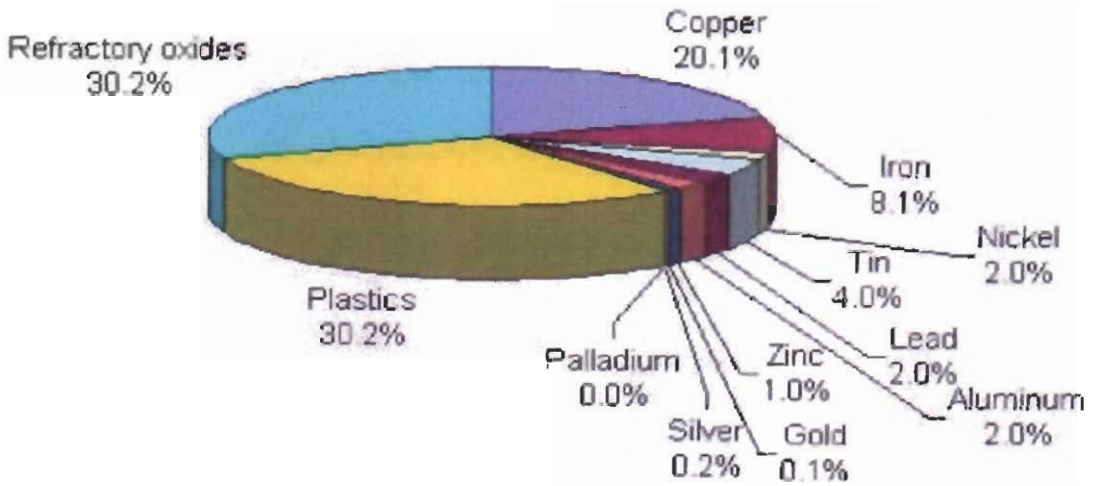

Figure 1: Typical material composition of electronic scrap

These toxic substances could pose threat to human health and the environment. Lead has been shown to affect the human body: Haematopoietic system (disruption in porphyrin synthesis, anaemai), blood system and kidneys in humans, and could cause serious negative effects on children's brain development (Neill, 1993).

Cadmium can cause harmful effects to target organs: lung and kidneys. Exposure to cadmium in the lungs can cause lung cancer, chronic bronchitis and emphysema (Neill, 1993). Mercury can be harmful to the kidney and gastrointestinal system, central nervous system and the respiratory system. Hexavalent chromium (Chromium VI) can produce toxic effects to cell and DNA. Incinerating electronic waste containing chromium can cause toxic effects to the environment (Wavra, 2000).

Poly brominated dipheny ethers (PBDE) can be harmful to animals and humans. A recent study of a plastic recycling process has shown that PBDE formed toxic polybrominated dibenzo furans (PBDF) and polybrominated dibenzo dioxins (PBDD) during the extruding process and were harmful to humans and the environment. In addition, exposure to polybrominated biphenyls (PBB) can possibly cause digestive and lymph system cancer (Silicon Valley Toxics Coalition, 2004).

Current Management of WEEE

The current management of electrical and electronic waste creates significant environmental problems. Most WEEE are landfilled, incinerated or recovered without pre-treatment. Electronic waste contains heavy metals and other toxic substances. Thus, incineration of these wastes cause adverse effects to humans and the environment. Dioxin is generated as a result of incinerating electronic waste containing copper. Incineration of

brominated flame-retardants generates toxic polybrominated disbenso dioxins (PBDDs) and polybrominated disbenso furans (PBDFs) (Eurochambres, 2000)

The study of the environmental impact of PVC indicated that incineration of PVC would create flue gas residues and could make air emission dangerous. According to the Directive 2002/96/EC on WEEE, member states should set up minimum standards for the treatments of WEEE to help protect human health and the environment (WEEE 2003). The European Union commission has adopted a directive on incineration of toxic waste, which provides emission limit values to reduce the emissions of various toxic pollutants into the atmosphere (Eurochambres, 2000). These include cement kilns, authorized power plants, the operation of waste incineration plants and measurement to prevent and reduce the adverse effect of incinerating of WEEE on human health and the environment.

Due to the hazardous substances contained in WEEE, the landfilling of these wastes would create adverse effects to the environment. According to the report from EPA, more than 3.2 million tons of WEEE ended up in the United States landfills in 1997 and in 2000, an estimated 300,000 tons of WEEE ended up in landfills. It can be estimated that the amount of WEEE will grow four-fold in the next few years (Global Futures Foundation, 2001). About 70% of heavy metals such as lead, mercury and cadmium found in landfills have contaminated the groundwater and pose threat to human health and environment (Global Futures Foundation, 2001).

According to the report from the green design initiative at Carnegie Mellon University, 50 million old computers will be landfilled by 2005 and 143 million recycled computers will be landfilled. Taberman (as cited in Wavra, 2000) stated that the main problems of landfilling WEEE are the leaching and evaporation of hazardous substances.

Leaching of cadmium and PBDE contaminants from plastic may be absorbed into the soil and groundwater and create acidic groundwater. Leaching and evaporating of lead from destroyed electronic equipment such as circuit breakers generates a specific problem. In addition, landfilling of these wastes could create a fire hazard if not properly controlled (Wavra, 2000).

Due to the WEEE landfilling problem, including the limited spaces for landfilling, European law limits the quantity of the waste allowed in landfills and requires a license to operate the landfill (European Union, 1999). The State of California Department of Toxics makes it illegal to dispose of CRTs in landfills (Global Futures Foundation, 2001).

Presently, the recycling processes of WEEE have been used to dispose of these wastes instead of landfilling. The purposes of WEEE recycling are not only to preserve the resources (Eurochambres, 2000) but also to reduce the hazard prior to disposal (California Against Waste, 2003). However, a recovery and recycling operation, if improperly treated, may result in increased human, environmental and public exposure to these hazardous wastes (California Against Waste, 2003).

Most of the electrical and electronic equipment waste in the United States has been sent to countries in Asia such as India and Pakistan to disassemble or recycle (EPA, 2001). Further, 80% of the electrical and electronic waste is actually exported to Asia, where it ends up in riverbeds or is illegally and improperly disposed of (Bell, 2002). Due to the high cost of disposing electronic waste, some manufacturers export their hazardous waste to the Asian countries to reduce this cost. These toxic wastes from oversea bear many adverse impacts, post threat to human health and cause environmental problems.

Even though this is meant to encourage recycling, the lack of producer responsibility still exists.

Hazardous Materials in Computer

Personal Computers can be disassembled into five categories:

a. Central processing unit (CPU) such as microprocessor
b. Input devices such as keyboard, mouse, scanner
c. Output devices such as video, monitor, printer
d. Memory storage devices such as RAM and CD-ROM drive, floppy disk
e. Communication network such as the bus (Ferrer, 1997)

These components contain the hazardous materials such as metal, plastics, CRTs and glass, and PCB (Yu, 2000). Table 1 presents the material used in a desktop computer and the efficiency of current recycling processes (Silicon Valley Toxics Coalition. 2004).

Electronic products contain a significant amount of plastic material. One computer contains approximately 13.8 pounds of plastic material. Thus, between 1997 and 2004, more than 4 billion pounds of plastic from computer waste was generated (Silicon Valley Toxics Coalition. 2004). Plastic mainly consists of polyvinyl chloride (PVC), which could cause harmful effect to humans and the environment. Thermoplastic materials are recyclable but the mixtures are unacceptable (Yu, 2000).

The computer video monitor consists of a cathode ray tube (CRT) (Ferrer, 1997). CRT is one of the materials that could cause environmental problems because it contains a large amount of lead, barium, and cadmium (Yu, 2000).

Table 1. *Electronics Industry Environmental Roadmap (Microelectronics and Computer Technology Corporation, 1996).*

Name	Content (% of total weight)	Weight of material in computer (lbs.)	Recycling Efficiency (current recyclability)	Use/Location
Plastics	22.9907	13.8	20%	includes organics, oxides other than silica
Lead	6.2988	3.8	5%	metal joining, radiation shield/CRT, PWB
Aluminum	14.1723	8.5	80%	structural, conductivity/housing, CRT, PWB, connectors
Germanium	0.0016	< 0.1	0%	Semiconductor/PWB
Gallium	0.0013	< 0.1	0%	Semiconductor/PWB
Iron	20.4712	12.3	80%	structural, magnetivity/(steel) housing, CRT, PWB
Tin	1.0078	0.6	70%	metal joining/PWB, CRT
Copper	6.9287	4.2	90%	Conductivity/CRT, PWB, connectors
Barium	0.0315	< 0.1	0%	in vacuum tube/CRT
Nickel	0.8503	0.51	80%	structural, magnetivity/(steel) housing, CRT, PWB
Zinc	2.2046	1.32	60%	battery, phosphor emitter/PWB, CRT
Tantalum	0.0157	< 0.1	0%	Capacitors/PWB, power supply
Indium	0.0016	< 0.1	60%	transistor, rectifiers/PWB
Vanadium	0.0002	< 0.1	0%	red phosphor emitter/CRT
Terbium	0	0	0%	green phosphor activator, dopant/CRT, PWB
Beryllium	0.0157	< 0.1	0%	thermal conductivity/PWB, connectors
Gold	0.0016	< 0.1	99%	Connectivity, conductivity/PWB, connectors
Europium	0.0002	< 0.1	0%	phosphor activator/PWB
Titanium	0.0157	< 0.1	0%	pigment, alloying agent/(aluminum) housing
Ruthenium	0.0016	< 0.1	80%	resistive circuit/PWB
Cobalt	0.0157	< 0.1	85%	structural, magnetivity/(steel) housing, CRT, PWB
Palladium	0.0003	< 0.1	95%	Connectivity, conductivity/PWB, connectors
Manganese	0.0315	< 0.1	0%	structural, magnetivity/(steel) housing, CRT, PWB
Silver	0.0189	< 0.1	98%	Conductivity/PWB, connectors
Antinomy	0.0094	< 0.1	0%	diodes/housing, PWB, CRT
Bismuth	0.0063	< 0.1	0%	wetting agent in thick film/PWB
Chromium	0.0063	< 0.1	0%	Decorative, hardener/(steel) housing
Cadmium	0.0094	< 0.1	0%	battery, glu-green phosphor emitter/housing, PWB, CRT

Note: Composition of a desktop personal computer based on a typical desktop computer, weighing ~60 lbs.

Printed Circuit Boards (PCB) contain a lot of heavy metal such as lead, chromium, zinc and silver. PCBs cause a lot of environmental concerns because the waste contained with PCB is hazardous. It generates pollution, energy and water consumption and is very difficult to recycle (Silicon Valley Toxics Coalition. 2004).

Computer batteries contain cadmium. Cathode ray tubs contain leads oxide and barium. Cables, plastic casing, and PCB contain brominated flame-retardants. Flat panel screens and switches contain mercury (California Against Waste, 2003).

Risk Management Plan

In order to manage the WEEE problem, risk management plans should be developed to protect health and the environment by preventing accidental releases of hazardous substances into the environment. Risk management can be defined as "the process of making and carrying out decisions that will minimize the adverse effects of accidental losses upon an organization" (MacWilliam, 2001 p.1). Risk Management is a sequence of a five-step process (1) identifying exposures to loss, (2) examining feasibility of alternative techniques, (3) selecting apparently best techniques, (4) implementing the chosen techniques, and (5) monitoring and improving the risk management program (Head & Horn, 1991).

The first step of the risk management is to identify loss exposure. Loss exposure can be categorized as (1) property losses, loss or damage of assets of the organization, (2) liability losses, injury or property damage to third parties, (3) personnel loss, injury of an organization's human resources through the course of their employment. Identification of loss exposure can be accomplished through surveys and questionnaires, financial statement analysis, analysis of past losses, documents and records, flowcharts, personal

inspections, and experts within and outside the organization. However, in order to develop risk management techniques for loss exposure, frequency and severity of loss exposure should be analyzed. The frequency of loss exposure refers to the probability that a given loss will occur, while the severity of loss exposure refers to the extent of the financial consequences of a particular loss (MacWilliam, 2001).

The second step after loss exposures have been identified is to examine feasible alternative risk management techniques to mitigate these exposures. These techniques include risk control and risk financing alternatives. Risk control alternatives involve either stopping losses from happening or reducing the frequency or severity of losses. Risk financing techniques are the method of generating funds to pay for accidental losses that risk control techniques cannot reduce the frequency, severity and predictability of accidental loss exposure (Head & Horn, 1991).

After examining the feasibility of alternative techniques, the next step is to select the best appropriate risk management alternatives in order to accomplish the organization's objectives. Risk control and risk financing techniques are examined to evaluate the short and long term effects, depending upon decision, cost and effectiveness analysis (MacWilliam, 2001).

Once a decision has been made, implementation of the chosen risk management techniques, monitoring and improving the results are the last two steps. Once implemented, the risk management program needs to be monitored to ensure that the program in place is effective and achieve the expectation of the organization (Head & Horn, 1991).

According to these risk management processes, a risk management plan should be developed to summarize the proposed risk management approaches. These approaches will cover the overall activities used to identify, analyze, manage, control and finance risk. A risk management plan also defines the overall risk policy and objective, resources, responsibilities, and documentations required for risk management activities.

However, in order to achieve the organization's goals, a risk management system should be implemented to provide a framework for managing risk. An effective risk management system contains six basic program elements: management leadership and employee involvement, hazardous prevention and control, training program (OSHA, 2003), standard implementation, measurement and evaluation, commending compliance and correcting deficiencies (Bird, 1992).

Top management leadership and employee involvement are fundamental for the success of a risk management system. Management directs the organization to establish and implement the risk management program to address disposal of electrical and electronic waste. Top management also provides the necessary resources such as staff, money, and time to ensure that all humans and environments are protected from hazardous wastes (OSHA, 2003). Top management develops and establishes a documented policy, goals, objectives and action plans to reach those goals and objectives. This policy includes a commitment to effective employee involvement, and compliance with the European Union directives and other related regulations. Top management is responsible for defining roles, assigning responsibility and accountability, and delegating authority to implement an effective risk management plan. In addition, top management

establishes and implements processes to encourage employee participation (American Industrial Hygiene Association, 2004).

OSHA provides suggested documents for management leadership and employee involvement. These documents include (1) worksite policy, (2) current goals, objectives, action plans, and program evaluation, (3) job descriptions, roles and responsibilities, (4) budget showing money allocated to safety and health, and (5) evidence of employees involvement such as record of employee participation or committee minutes (OSHA, 2003).

Top management ensures that hazards will be eliminated and exposure to hazards will be controlled. The organization should implement specific, clear, and demanding standards for all work activities and all program elements. Frank D. Bird, Jr (1992), stated in the loss control management "Measurement involves comparison with standards. Without adequate standards, there can be no meaningful measurement evaluation or correction of performance. You cannot manage what you cannot measure" (Bird, 1992, p. 49).

The organization should implement an effective training and education program to ensure that all employees are provided with necessary job information. This program includes the basic training on the performance of the job, safety and health responsibility, specific training topic such as hazard recognition program, hazard communication, hazardous waste regulation, and other related topics (OSHA, 2003).

The organization develops and establishes processes to evaluate the performance of risk management plan through a monitoring and measurement program. The results of measurement and monitoring activities determine whether this risk management plan

obtains goals and objectives. The organization measures its performance by degree of compliance with standard implementation (Bird, 1992). Corrective and preventive actions are provided to address and control risk and hazard that could cause serious injury and illness. Performance tracking is taken to ensure the effective implementation. The findings from the performance evaluation, corrective, and preventive action provide feedback information, which help improve the planning process. Top management reviews and participates in evaluation of the performance of risk management leaders and processes. The purpose of management review is to evaluate how well the risk management system is integrated with other management systems, to address the recommendation for improvement, and to determine its effectiveness (American Industrial Hygiene Association, 2004).

Recovery, Recycle, Remanufacturing and Takeback Program

The personal computer has a short life cycle. While the number of personal computers is increasing as a result of the rate of technological change in computer software and hardware, the disposal of these electronic wastes represents a significant environmental concern as a result of power consumed, material used, or end-of-life product consideration (Yu, 2000). To comply with the WEEE directive, many manufacturers have developed a takeback program and other recovery and recycling technologies, which are compatible with their products.

Many manufacturers in the United States such as Apple Computer, Best Buy, Compaq, Dell, Hewlett Packard, IBM, Sharp, Sony, Phillips, Panasonic, and Xerox have an electronic waste program either by using environmental design or by making their products easy to disassemble, dismantle or recycle (EPA, 2002).

IBM has designed a product take back/recycling program around the world. Due to the end-of-life product problem, IBM provides an asset recovery solution program to small and midsize business (SMBs). This serves as a flexible solution to get rid of old computer equipment. It established a recycling service program to recycle any manufacturer's personal computer and other computer supplies such as printers, ink cartridges and scanners (IBM, n.d.).

In the period 1994-1997, IBM recycled over 30,000 ton of computer products. Fifty million dollars are saved in using refurbished parts and components. Ten million dollars were gained from selling used parts and components to retailers around the world. Finally, five million dollars were gained from the sale of materials extracted after recycling (EPA, 2002).

Apple Computer has improved product design by reducing average power consumption and introducing a modular design, which is easy to assemble and disassemble. Apple Computer manages and disposes their products at the end of its life (Apple Computer, 2004). Apple Computer also encourages recyclability of the product by using recyclable materials and reducing the material and weight used in the product. It also has standardized design processes and components to simplify material used in product lines as well as making and using materials with international recycling codes (EPA, 2002).

Compaq has focused on a design for the environment during every phase of its product's lifecycle. Many of its products are designed to be recycled and upgraded. Compaq promoted the United Recycling Industries' (URI's) Electronics takeback program in June 2001. This program encourages customers to return the end-of-life

products to the company. It provides the participating customer 6% to 9% percent discount on Compaq products. The URI's program is offered to residents and small businesses in seven states in the Midwest. The program provides shipping boxes and labels to return the end-of-life product. The customer has to pay URI $27.99 for up to 70 pounds of returned monitors, computers, and peripherals (EPA, 2002).

Dell has established a Personal Computer Recycling Service, which is an efficient and environmentally safe disposal process for non-functional or outdated equipment. In 2003, Dell Computer Corporation conducted a recycling tour in 15 cities including Austin, Texas and Portland, Oregon in order for customers to donate or recycle unwanted computer equipment or the end-of-life computer free of charge. Dell Computer also offers three options for customers to address the end-of-life product, either Dell or non-Dell products through an online system. The first option is to pay Dell $15 to pick up the end-of-life product and ship to a recycling center. The second option is to donate the end-of-life products through the National Christina Foundation (NCF). The NCF is a non profit foundation dedicated to support training through donated used technology. The last option is auction through the Dell Computer website. In addition, Dell Company designs products that are easy to upgrade and recycle and dismantle simply and economically (EPA, 2002).

In May 2001, Hewlett Packard (HP) developed improvements in design that facilitate disassembly. It offers a computer takeback program or product end-of-life return program for HP and other manufacturers' hardware. This program helps ensure that the unwanted hardware or HP printing supplies are recycled in a way that conserves resources and aims to reuse, recycle and dispose of the end-of-life product. The cost of

the service ranges from $13 to $34 per item depending on the quantity and type of product returned (Yu, 2000).

HP has also developed a design product. The first step is "using a foam chassis that reduces the parts needed for some products, simplifies disassembly, and reduces the amount of protective packaging required during shipping." The next step is "identifying the resin content of plastic parts by marking the plastic instead of using a paper label to facilitate recycling" (Yu, 2000).

Instead of landfilling or incinerating WEEE, which could be harmful to humans and the environment due to leaking or burning of heavy metal, electronic waste can be recycled. Dr. Todd Randall provided three basic steps in researching a "Sustainable Solution for E-waste" for the recycler. The first step is to reuse or sell any computers, parts and components that are still useful. The second step is to refurbish products that are still useful if they are slightly updated. The last step is to recycle every possible part of the product to recover valuable parts such as metals, even though these metals might be harmful to humans and the environment. These approaches would help promote efficiency and ensure maximum profit and preserve the environment (Ruel, 2003).

A recycling process is one of the methods to help reduce the electronic waste. However, computers are difficult products to recycle, due to the toxic components and their designation, which is difficult to disassemble (California Against Waste, 2003).

The study of the economics of manufacturing personal computers by Geraldo Ferrer indicated that a simple method to recover waste from personal computers was to disassemble the entire computer and recycle ferrous and nonferrous metal, plastic or glass

(Ferrer, 1997). Figure 2 represents the personal console recovery process to disassemble used computers for recycling, reuse, upgrade and reassembly.

Milojkovic (2002) provided a list of elements, compounds and components, which may be reused in the computer industry. The elements include platinum, Gold, Palladium, Silver, nickel, Copper, Zinc, Aluminum and Mercury. The compounds include ABS-FR plastic, Stainless steel, PVC, polyethylene, PCBs, Glass, and Steel. The components include integrated circuits, monitors, power supplies, displays, Lead acid batteries, and NiCd batteries.

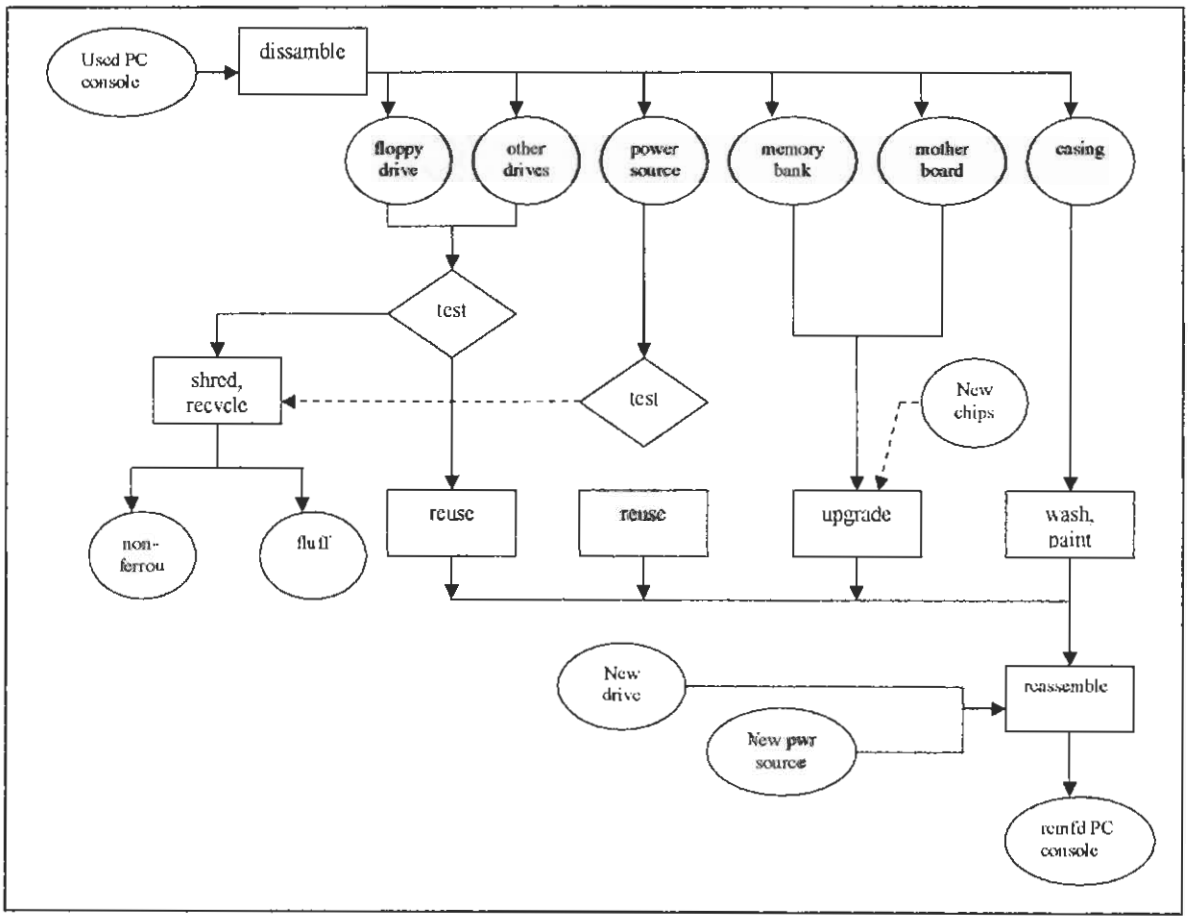

Figure 2: PC console recovery process

According to the Hewlett-Packard recycling center in Grenoble, France, more than 100 tons of computers and their accessories, such as returned printer cartridges, that could not be reused were recycled per month. Some parts are disassembled into key commodities such as, aluminum, steel, copper or plastic. Some parts are sold as raw materials to the manufacturers for making new products (EPA, 2002). Boards, hard discs and other power sources were recovered. Floppy disc drives and microchips were sold. Printer toners and ink-jet cartridges were remanufactured. Toxic materials such as batteries and CRTs were disposed of safely. Precious metals, copper cables, and metal casings were recycled and plastic materials were recycled or incinerated. Three percent of all parts are landfilled and about 10% of all parts came from the take back scheme (Ferrer, 1997).

Figure 3 shows the architecture system of recycling identification. After the personal computers were disassembled, each of the components were classified or separated into various groups such as PCB, plastics, ferrous and non-ferrous metals, monitors, motors, cables and batteries for further recycling processes or other treatment processes. The next step was to pre-treat these materials by shredding to separate different materials. These materials were recycled, reused or landfilled depending upon the environmental decision.

However, the materials obtained from recycling processes should have the characteristics of virgin materials. In addition, the price of the materials obtained from recycling processes should be lower than the virgin ones. The recycled materials may be used as new products or raw materials in the production of products (Yu, 2000).

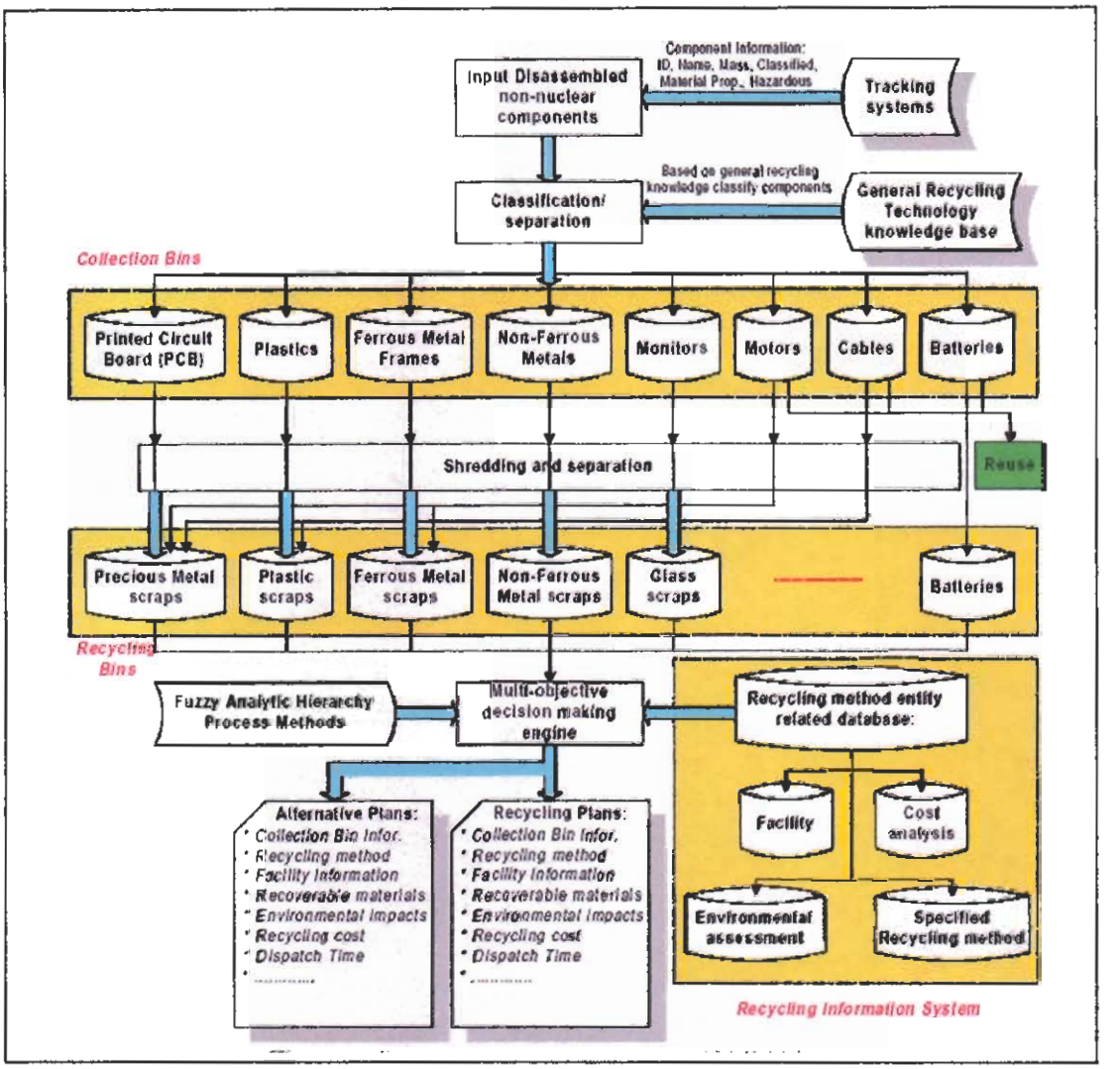

Figure 3: System Architecture of Proposed Methodology

Eco-design

The interaction of the electrical product and the environment can be viewed as energy consumption, pollution by used electrical and electronic products and pollution caused by toxic substances. Electrical and electronic product uses a gigantic amount of energy. They also have tremendous impact on the environment because of the toxic and non-toxic components. This fact reveals the idea of how a product affects the environment and provides a clue on perceptions of eco-design. Eco-design is defined as a

systematic approach for a product design not only to encompass the economic, functional, and esthetic aspect, but also to protect health, environment, and society during the whole life cycle of the product (Milojkovic, 2002). Eco-design integrates the environmental aspect into product design and is considered a component of environmental management. The purpose of eco-design is to minimize the impact on the environment without impairing the quality of the product use (Ademe, 2001).

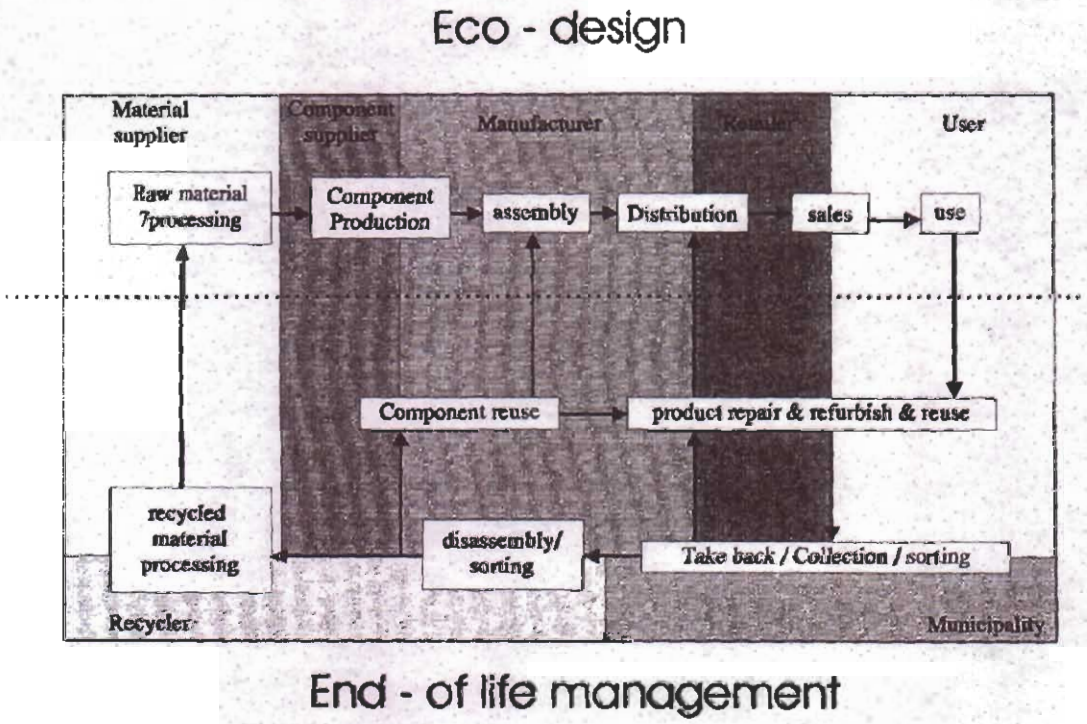

Figure 4: Eco-design and end-of-life management interrelation

The complete life cycle of the product and the interrelation between eco-designs and end-of-life management were shown in Figure 5. The product's life can be divided in phases: raw material processing, component production, assembly, distribution, sales and use. Each of these phases has an eco-aspect (Milojkovic, 2002). Raw materials should be processed with minimum energy consumption. The amount of waste generated should be

minimal as well. Products should be easy to dismantle and disassemble. The end-of-life management includes several activities: product takeback, collection and sorting; product repair, refurbishment and reuse; component reuse; disassembly and sorting; and recycled material processing. Once the product is taken back or collected, it may be reused after repair or refurbishing. Some components extracted in the disassembly process may be used as spare parts in the assembly process. In the recycled material processing, some of materials may be useful for future use. They may be used as raw materials instead of final disposal on landfill or incineration (Milojkovic, 2002).

Milojkovic (2002) discussed design processes including design for reuse, design for recycling and sustainable design. Design for reuse includes a process that converts products in order to be reprocessed. It is important to dismantle products effectively in order to reuse the components. Design for recycling includes the process that uses a small number of materials and components during the production phase. This process makes it easier to extract valuable components and materials. Sustainable design aims to develop a product, which reduces the use of raw materials and energy, and exhibits low production cost, high durability, high functionality, high reliability, and environmental friendliness during its life cycle.

Life cycle analysis is one of the sustainable design tools. Life-cycle analysis (LCA) is used in product design aid. It helps the product designer in the design process to reduce the environmental impact of products (Andrews, 2000). The personal computer has a short life cycle compared to other electronic products such as Televisions, refrigerators and automobiles. The increasing number of obsolete computer products is a result of the rate of technological change in the computer software and hardware

industries. According to the Electronic Product Recovery and Recycling Baseline Report, published in 1999 by the national Safety Council, over 20 million personal computers became obsolete in 1998; the average lifecycle of the computer monitor is four to seven years; scanner and printer is three to five years and the lifecycle of the personal computer is around three years. In addition, by the year of 2005, the lifecycle of the personal computer would decrease to two years (National Safety Council, 1999).

The lifecycle analysis has been studied to determine the computer lifecycle impact on the environment. The recent study of lifecycle assessment from Masafumi Tekawas (Andrews, 2000) indicated that the lifecycle of computer and its consumption of resources could impact the environment through the eutrophication, acidification and greenhouse effect. Another study from Ueno, Shiino and Onishi, also indicated that material used in the production stage of computer components had a significant environmental impact (Ueno, 1999).

The set of ISO 14000 standards is another tool that aims to protect environment and implement and improve an environment management system. The ISO 14000 series include the ISO 140001 environmental management system (EMS) and other standards such as environmental assessment (ISO 14010 series), environmental performance evaluation (ISO 14030 series), life cycle analysis (ISO 14040 series) and environmental aspects into design and development (ISO 14060 series) (ISO 14000, 2002).

The guiding principle for eco-design consists of the following areas:

- Define the purpose of the approach such as improving the existing product or eco-designing a new product

- Take into account the lifecycle. This includes service provided by the product, quantifying of functional unit, and identifying the stages of the lifecycle.
- Identify the sources of impacts such as identifying in-coming and outflows and assessing their impacts on the environment.
- Suggest possible improvements. This includes indicating the factors which generate the main impact and suggesting possible improvements to mitigate them

Key factors for improvements in eco-design are choosing low-impact materials and substances, reducing the quantity of materials, optimizing production techniques, optimizing packaging and logistics, optimizing product life and end-of-life product, and reducing impact during product use (Ademe, 2001).

Milojkovic (2002) provided examples of eco-design and sustainable design on personal computers as follows: "Lower the clock speed on the motherboard to a slow mode, usually 8 MHz. Shut down all disks and stop all synchronization signals at the video controller. Stop the processor clock, putting the DRAM in slow refresh. Suspend to disk all DRAM and control registers, and then power off the entire system, leaving a small auxiliary power supply to some circuits to allow them to awaken the sleeping machine" (p.97).

Impact of WEEE and the Proposed Legislation in Thailand

The WEEE and RoHS directives have directly affected the electrical and electronic equipment manufacturing industry in Thailand. These directives are based on the concept of Extended Producer Responsibility (ERP), which means that producers of electrical and electronic equipment are responsible for takeback and disposal of their end of life product. Many companies in Thailand have difficulty exporting their products to

Europe and the United States. For many years, only large companies or SME companies that have been contacted through the parent company in other countries try to implement a program to comply with the legislation. However, the member states of European Union have mandated legislation regarding electronic waste and enforce regulation in their country. Consequently, these directives will affect investment of new equipment or processes due to the cost of implementing new regulations. The cost of exporting products in compliance with new regulations is still unknown.

In order to achieve a sustainable solution to the electronic waste problem, legislation must change the way business operates. On the other hand, legislation must require producers to be responsible for takeback and management of their products. Current legislation should comply with the European Union (EU) or follow legislation in other countries such as United States.

The Federation of Thai Industries (F.T.I.) and Ministry of Commerce Organization have joined with the European Union to set up a process, make networking, and handle expenses involved in complying with the legislation.

In spite of the fact that electrical and electronic waste contains significant hazards, which pose threats to humans and environments, it is not classified as a hazardous waste when disposed. In Thailand, no legislation currently exists that addresses the disposal of WEEE. All electrical and electronic wastes are treated as general waste.

A similar situation exists in the United States. Currently, no national legislation is in effect regarding electronic waste. There have been efforts to pass legislation but the legislation was not enacted. A few states have introduced electronic waste legislation. Californians Against Wastes provides, through a website, lists of 26 states that have

introduced a bill on electronic waste legislation. Many states such as California, Florida, Michigan and Virginia have adopted a law to ban cathode ray tubes (CRTs) from landfills and incinerations. Other states, such as New York, require manufacturers to create a list of electronic equipment containing hazardous materials and to establish collection and/or disassembly centers that retrieve at least 90% of electronic waste generated. These hazardous wastes contain lead, CRTs, printed circuit boards, PCB-bearing components and mercury-bearing components (Californians Against Wastes, 2003).

Summary

The literature review addressed the waste from electrical and electronic equipment problem in Europe, the United States, and Thailand. The current management of electrical and electronic waste creates significant environmental problems. Most of WEEE are landfilled, incinerated or recovered without pre-treatment. Producers are responsible for improving environmental quality of the products and decrease the quantity of waste. The review demonstrated that to comply with the WEEE directive, many manufacturers have developed a takeback program and other recovery and recycling technologies, which are compatible with their products. Eco design and life cycle analysis were systematic approaches, which integrated environmental aspect into product design. The main objective was to achieve and maintain compliance with regulation in the design and production processes. The WEEE and RoHS directives have directly affected the electrical and electronic equipment manufacturing industry in Thailand. Many companies in Thailand have difficulty exporting their products to Europe and the United States.

The current Thai regulations have not been legislated for the disposal of waste electrical and electronic equipment. Currently, there are no specific programs to take back the end-of-life product and no effective procedure for recovery, reuse or to recycle the product following the requirement of the European Union directives.

CHAPTER III: METHODOLOGY

Introduction

The main objective of this chapter was to describe the methods and procedures used in this study. The methods and procedures included a review of literature pertaining to WEEE and RoHS directives. Semi-structured interviews were conducted with two organizations. These organizations have implemented or are exploring the alternatives of starting a program to deal with electrical and electronic waste.

The purpose of the study was to develop a risk management program to address the disposal of waste from computers and computer components and to assist Thai companies in complying with the WEEE and RoSH directives.

The objectives of this study were:

1. To identify best practices to address waste from electrical and electronic equipment.
2. To identify possible redesign alternatives.
3. To develop a risk management plan to address disposal of electrical and electronic waste to comply with the WEEE and RoSH legislation from European Union.

Subject Selection and Description

Two companies that manufacture electrical and electronic equipment were selected to participate in this study. One of those has implemented a program and the other is exploring the alternatives of starting a program to deal with the electrical and electronic waste and to comply with the directive from the European Union.

The companies that participated in this study were not identified by company name. One company was identified as ABC and another company was identified as XYZ.

Two safety professionals were interviewed based on the problem regarding electrical and electronic waste. The safety professional at ABC Company was the Environmental Health and Safety Engineer and the safety professional at XYZ Company was the Director of Environmental Health and Safety.

Instrumentation

The literature review was conducted using available print and electronic media to analyze the general theme of each objective. This literature provided information on WEEE and RoHS directives; current management of WEEE; hazardous waste regulation; hazardous materials in computer; recovery, recycle, remanufacturing and takeback program; and eco-design.

The interview format was semi-structured. The questions were developed from the literature review to address the objectives of the study. The interview guide covered the following: hazardous waste regulation involving electronic waste, WEEE and RoHS directives, takeback program, recycling, reuse and recovery program, and other disposals of electrical and electronic waste such as landfilling, incineration, selling or exporting these wastes. A personal interview guide is provided in Appendix B, "Interview Guide".

Data Collection

Two safety professionals from electrical and electronic equipment manufacturing companies were initially contacted by phone and email. They were informed about the intent of the study and were asked to participate. The participants had the choice of whether or not to participate in this study. Once the participants accepted, they were then asked to complete a consent form. The questions for interview were provided to the participants one week before the scheduled interview. The researcher interviewed two

safety professionals in person and both interviews were recorded. Both manufacturing companies were located in the Midwest.

Data Analysis

The primary objective of this study was to develop a risk management plan to address the disposal of electrical and electronic waste to comply with the WEEE and RoSH legislation from European Union. The data gathered from the literature review and the interview conducted was analyzed in the following areas:

1. The arrangement, management, and awareness according to the legislation from the European Union and the United States.
2. The Extended Producer Responsibility (EPR) program regarding computer manufacturing
3. The disposal of electrical and electronic waste program such as takeback program, recycling, reuse and recovery program, and other disposals of electrical and electronic waste program.

Limitations

One limitation of the instrument was that there was no measurement of reliability and validity because only two companies participated in this study. One manufacturing company has currently implemented such a program to deal with the electrical and electronic waste, while another manufacturing company has explored the alternatives of starting such a program to deal with the electrical and electronic waste.

During the interview, the interviewee could have misinterpreted the question from the researcher. Also, the researcher could have misinterpreted some answers from the participants.

CHAPTER IV: RESULTS

Introduction

This chapter provides the results of the study. The results of this study will provide information regarding electrical and electronic waste management through findings found from interviews and the literature review of Chapter Two.

The purpose of the study was to develop a risk management program to deal with the disposal of waste from computers and computer components and to prepare Thai companies to comply with the WEEE and RoSH directives.

The objectives of this study were:

1. To identify best practices to address waste from electrical and electronic equipment.
2. To identify a possible redesign alternative.
3. To develop a risk management plan to address disposal of electrical and electronic waste to comply with the WEEE and RoSH legislation from European Union.

Demographic Information

Two safety professionals from electrical and electronic equipment manufacturing companies were selected for this study. One company has implemented a program and one is exploring the alternatives of starting such a program to address electrical and electronic waste issues. Both interviews were recorded and lasted 40 minutes.

Best practices - Objective 1

The literature review and interviews identified best practices to address WEEE concerns.

1. Two safety professionals from Company ABC and XYZ were knowledgeable with regard to hazardous waste regulations involving electronic waste. Both safety professionals believed electrical and electronic equipment manufacturers should be responsible for waste generated.
    a. Company ABC has raised the awareness within the company of the need for new hardware products to meet the requirements of European Union (EU) directives known as RoHS and WEEE. The company recognized that it was important to achieve compliance with the requirements of the directives in order to maintain the segment of sales and delivery of company products into European Countries. Company ABC has implemented a Design for the Environment (DFTE) system for several years. The main objective was to achieve and maintain compliance with regulation in the design and production processes. Company ABC set up DFTE team members to discover and address issues impacting the company. In addition, senior management has supported the DFTE system and each manager accepts the recommended responsibility and becomes engaged with the early work. Company ABC set up a timeline and allocated funding to implement programs to comply with WEEE and RoHS directives.

b. Company XYZ was a leader in product stewardship and environmental responsibility. Company XYZ considered WEEE and RoHS directives in their product development cycle. Life Cycle Management (LCM) and Design for Environment (DFE) were two tools that the company used to maintain a market in both existing products and new products. An electrical and electronic product responsibility team has existed for several years and was responsible for WEEE and RoHS issues. Members of the steering committee were appointed to identify environmental, health and safety issues.

2. Company ABC has policies and procedures to deal with the end-of-life product and also established processes for proper disposition of electrical and electronic waste. Company ABC has not implemented a takeback program to take back the end-of-life products, however the company had local site management, which was responsible for inventory of electronic equipment for disposal. Hazardous materials were removed from electronic equipment in this local site. Disposition of electronic waste was performed environmentally and economically. Some of the end-of-life products were shipped to another facility for recovery.
3. Company XYZ does not have programs to promote compliance to WEEE directives. The company focused only on Life Cycle Management (LCM) and Design for Environment (DFE) dealing with health, safety and environmental issues. However, Company XYZ has explored the alternatives of starting a program to handle the electrical and electronic waste. These programs would include (1) developing a product process and control to comply with WEEE and

RoHS directives, (2) offering a product takeback program to be coordinated by XYZ managers in Europe, and (3) developing a chemical data management system for past and future customers and for compliance with WEEE and RoHS directives.

4. Only Company ABC had a recovery, recycling, and reuse program to meet WEEE and RoHS directive requirement. Most electrical and electronic products at the company were purchased from other companies. However, these companies had no takeback program in place. Thus, Company ABC generated and took care of all end-of-life products by itself. Much electronic waste generated was collected at a local site management plant. At this local site, electronic waste including types of equipment and quantity of components was listed on an electronic equipment sheet. The electronic waste was then shipped to another facility called a recovery site. At this recovery site, electronic waste was disassembled and recovered. Some components might be reused as spare parts. Some components might be resold to other parties. The components that were not recovered, reused, and recycled were sent to another facility for disposal in a proper manner.

The results from literature review answer the next two objectives listed in the statement of the thesis. These results will provide information on redesign alternatives and risk management plan to address of disposal of electrical and electronic waste to comply with the WEEE and RoHS legislation from European Union.

Redesign Alternative – Objective 2

Figure 5 describes the major activities and tasks for redesign alternatives. The main purposes of redesign alternatives are waste prevention, improved resource management, and compliance with WEEE and RoHS directives. Figure 5 provides steps that served as a model for new product designs.

Process Map 1
Redesign Alternative

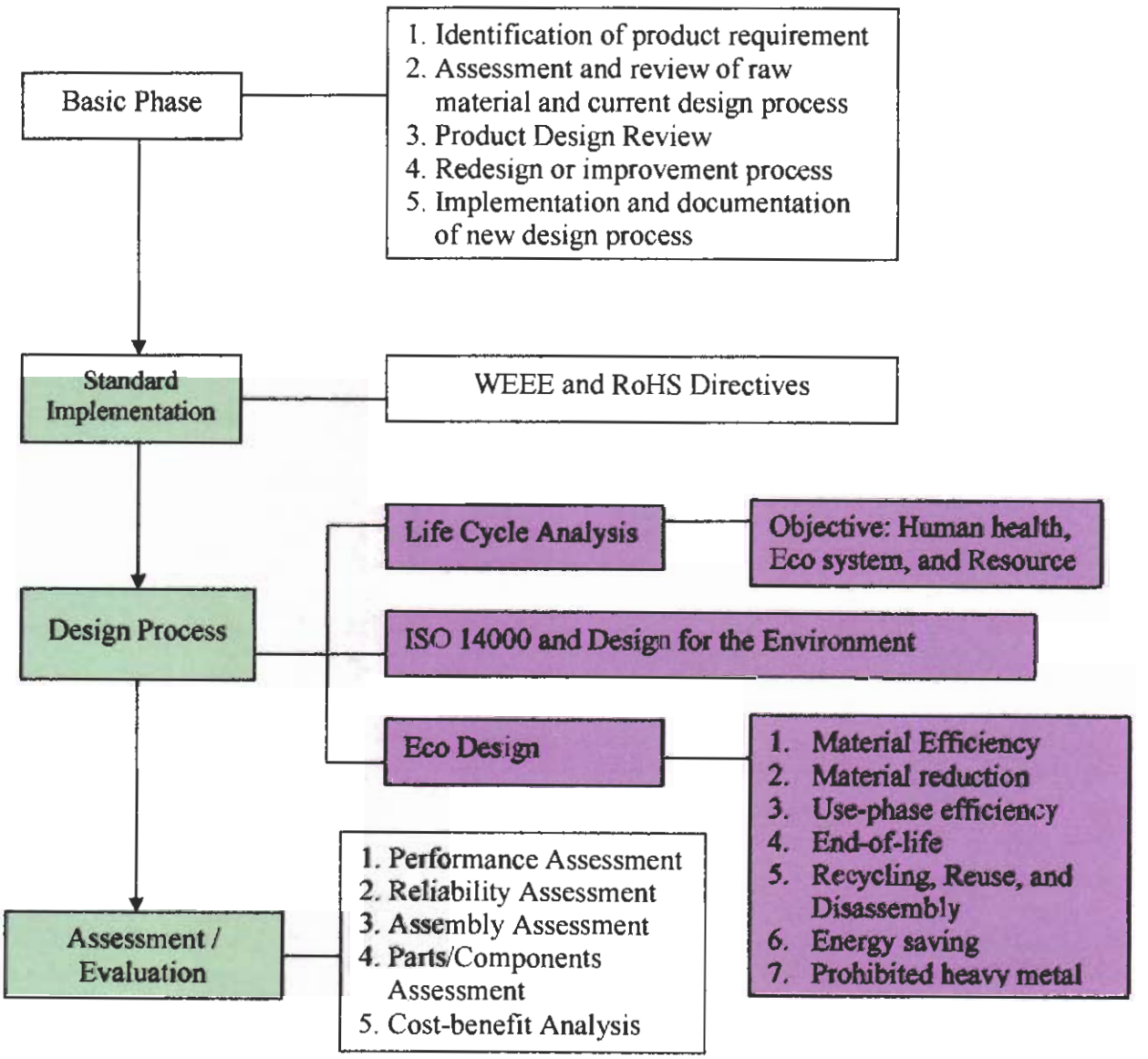

Figure 5. Process Map 1: Redesign Alternative

The "Basic Phase" indicates that the first need is to identify requirements and to examine components of the product. The next steps are to review the product design and to assess and review raw materials and the current design processes. The final step is to develop a redesign process plan, implement and document the new product design process plan.

The "Standard Implementation Phase" involves effectively implementing of regulatory standards. These standards should comply with and meet the requirement of WEEE and RoHS directives. The directives aim to minimize and prevent generated waste, to restrict the use of hazardous substances, and to encourage reuse, recycling, recovery, and remanufacturing of products.

The "Design Process Phase" breaks the process into more discrete steps, which include Life Cycle Analysis, ISO 14000 Standards, and E-co Design. These three steps are redesign alternatives, which integrate the environment into product design.

1. Life Cycle Analysis (LCA) helps determine the environmental impact of the product's life cycle. LCA focuses on human health, eco-system, and resources used in the process.
2. The set of ISO 14000 standards is another tool that aims to protect the environment and implement and improve an environmental management system.
3. Eco design is a systematic approach for a product design, which integrates economic, function, esthetic and environmental aspects in product design processes. Eco design strategies are designed for (1) material efficiency, (2) material reduction, (3) energy efficiency and energy saving, (4) disassembly,

reuse, remanufacturing, and material recovery, and (5) compliance with directives.

The final step in the Figure 5 is to assess and evaluate the redesign alternatives. This step includes (1) performance assessment to ensure that the product *can work*, (2) reliability assessment to ensure that the product *will not fail*, (3) part and component assessment to ensure that the product *complies with RoHS directives*, (4) assembly assessment to ensure that the product *can be made*, and (5) cost-benefit analysis to ensure that the product *can generate a profit, or break even.*

The Risk Management Plan – Goal 3

Figure 6 describes the risk management model to address of disposal of electrical and electronic waste to comply with the WEEE and RoHS legislation from European Union and other regulations.

Goals and Objectives. The organization defines scope, goal, and objectives for a risk management plan to address the disposal of electrical and electronic waste. The purpose of this plan is to prevent electrical and electronic waste, reduce the disposal of waste, and improve environmental performance. The organization develops and establishes a documented policy, which includes a commitment to effective employee involvement, and compliance with the European Union directives and other related regulations. Definitions are also provided to explain some technical terms.

Process Map 2
Risk Management Plan

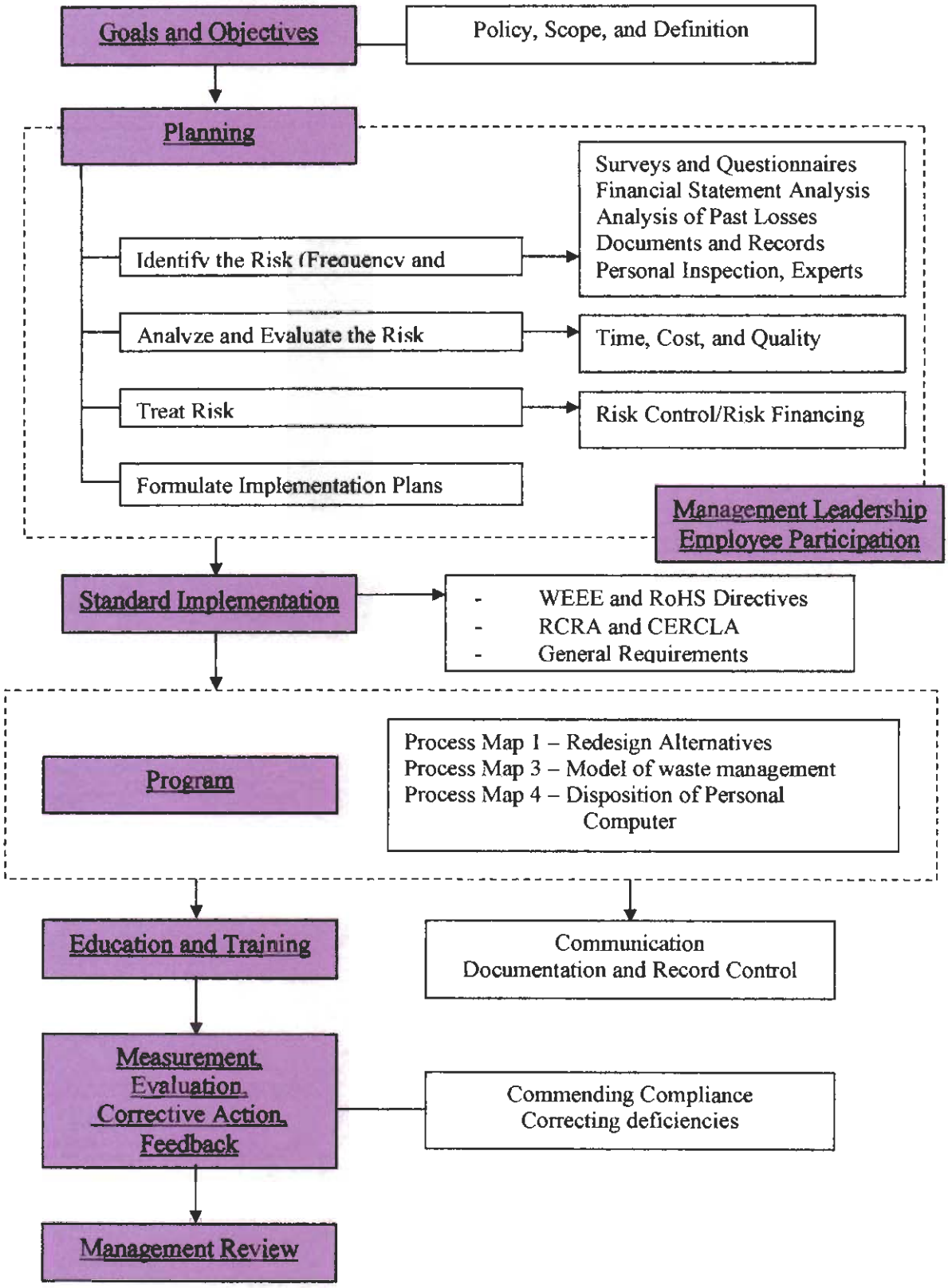

Figure 6. Process Map 2: Risk Management Plan

Planning. This section defines the planning requirement for a risk management plan. The purpose of this planning process is to identify the risks associated with electrical and electronic waste, analyze and evaluate the risks, and develop the control method to treat that risk. The next step is to formulate implementation plans to meet the goal and objectives.

Management leadership and employee participation. This section defines the requirements for top management leadership and employee participation. Top management directs the organization to establish and implement the risk management program to address disposal of electrical and electronic waste. Top management provides necessary resources such as funds, staff, and time to ensure that all human and environment are protected from hazardous wastes. Top management also encourages employee participation. Employees get involve in planning, implementing, and evaluating of risk management plan.

Standard Implementation. This section defines effective implementation of regulatory standards on electrical and electronic waste. These standards should comply with and meet the requirement of WEEE and RoHS directives, and other related regulations such as RCRA and CERCLA.

Program implementation. This section defines programs that are required for implementation of risk management plan. These programs include redesign alternative program "Figure 5", End-of-life management "Figure 7", and disposition of personal computer "Figure 8". In addition, the organization establishes and develops the process to communicate information on risk management program and implement the effective document and record control processes.

Education and Training. This section defines education and training programs to ensure all employees are provided with necessary job information. These programs include (1) the basic training on the performance of the job, (2) safety and health responsibility, (3) recycling, reuse, recovery program, and (4) disposal program of electrical and electronic waste.

Measurement, Evaluation, Corrective Action and Feedback. This section defines processes to measure performance by degree of compliance with standard implementation and processes to evaluate the overall performance of a risk management plan through monitoring and measurement programs. The results of measurement and monitoring activities determine whether this risk management plan reaches goals and objectives. Corrective and preventive actions are provided to address and control deficiencies in performance standard. Performance tracking are taken to ensure the effective risk management plan implementation. The lessons learned and findings from the performance evaluation, corrective, and preventive action are feedback information, helps improve the planning process.

Management Review. This section defines processes for top management to review and participate in evaluation of risk management leaders and processes. The purpose of management review is to address the recommendation for the improvement of risk management plan and to determine and evaluate how effectively the risk management plan is integrated with other management systems.

End-of-life management

Figure 7 describes risk management plan to deal with the disposal of electrical and electronic waste. The first part of the Figure 7 represents a process flow of the product. This process flow can be fragmented in phases: redesign alternatives, raw material, part and component production, assembly, finished goods, distribution, and the consumer. Each of these phases has environmental aspect.

After redesign alternatives are developed, the first phase is to choose raw materials with less toxic and minimum waste for disposal. In complying with WEEE and RoHS directives, prohibited substances cannot be used in the process. Parts and components should be easy to dismantle and disassemble. These products should be designed to produce minimum waste and to consume low levels of energy. The product is designed and developed for reuse, remanufacturing, and material recovery. The distribution phase is related to reducing waste generated from the packaging. The final phase "consumer" becomes very important from environmental perspective. Consumers should be encouraged to purchase the product that does not negatively impact the environment even though the price may be high.

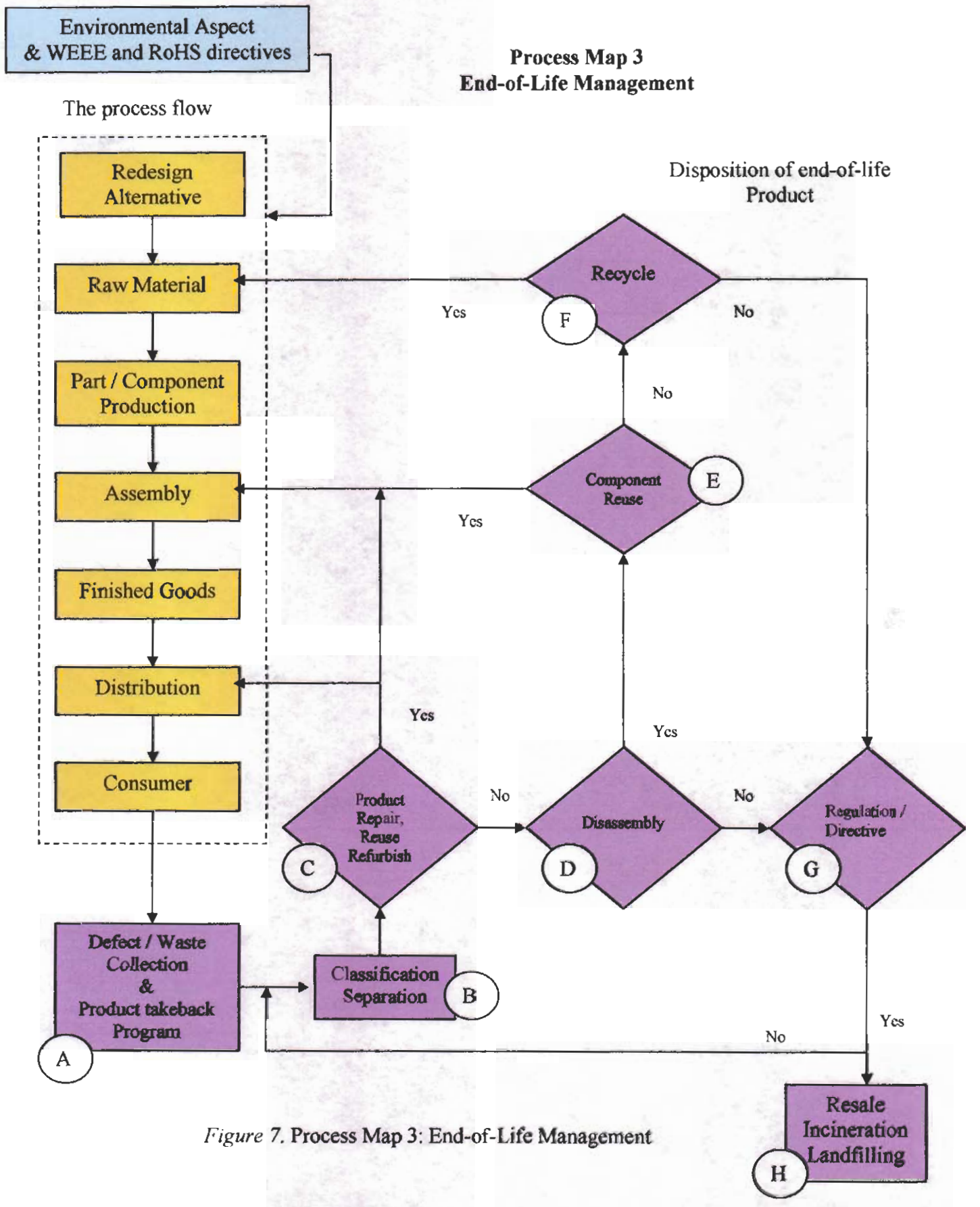

Figure 7. Process Map 3: End-of-Life Management

The second part of the Figure 7 represents disposition of the end-of-life product. Electrical and electronic products are taken back through "Product Takeback Program (A)". This program includes waste and defect collection from a process flow of the product. The next step (B) is to separate and classify these products that are taken back or are defective. After products are repaired or refurbished (C), they can be resold at the distribution phase or are sent back to the assembly line for remanufacturing. Some components that cannot be reused, repaired or refurbished will be extracted in the disassembly process (D). After being extracted, some components may be reused as spare parts (E) in the assembly process.

The unused components will be recycled in the recycled material processing (F). Some of the materials may be useful for future use as raw materials. Some components that cannot be recycled and disassembled must comply with standards and regulations (G) before resale or final disposal in landfills or by incineration (H). These standards include WEEE and RoHS Directives, and environmental regulations on electrical and electronic waste. If the product does not comply with these standards and regulations, these components will have to pass through the "disposition of end-of-life product" process again to meet requirements of environmental aspects.

Disposition of Personal Computer

Figure 8 describes the risk management plan for disposition of personal computers. After personal computers are taken back through product takeback programs, they will be disassembled into components. The next step is to classify and separate these computer components into two groups: X and Y as follows:

Table 2. *Classification of Computer Components*

X	Y
1. Printed Circuit Board (PCB)	1. Floppy and Other Drives
2. Ferrous Metal Frames	2. Memories
3. Non-Ferrous Metals	3. Casing and Cables
4. Motors	4. Power Sources
5. Plastics	5. Mother Boards
6. Monitors	6. Monitors and Batteries

Note: this does not include other accessories such as keyboard, mouse, scanner, and modem.

The X group represents components, which are difficult to repair, reuse and refurbish. The components in the X group need to be treated before landfilling or incinerating.

The Y group represents components, which may be useful for future use. The components in the Y group need to follow a procedure before resale.

Components in the X group are pre-treated by shredding or other separation methods. However, some materials are prohibited from being shred because of hazardous material content. Materials retrieved from the shredding or separation processes are recycled in recycling bins. These six recycling bins are for precious metal scraps, ferrous metal scraps, non-ferrous metal scraps, plastic scraps, glass scraps, and other scraps. However, recycling processes are identified depending upon decision making and other factors such as recycling method, cost analysis, environmental impact, dispatch time, recoverable materials and facility information.

Process Map 4
Disposition of Personal Computers

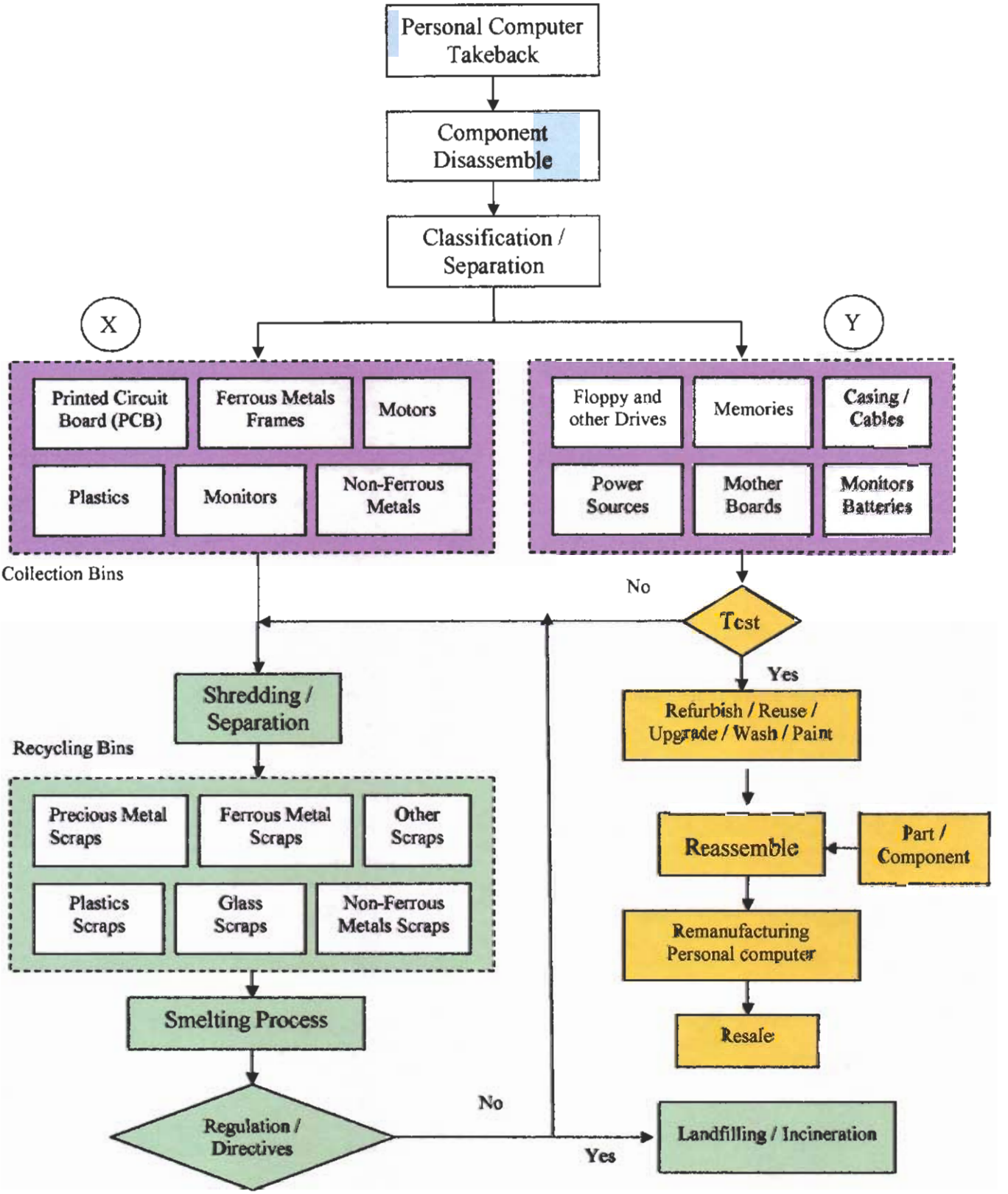

Figure 8. Process Map 4: Disposition of Personal Computers

Materials that cannot be recycled are smelted in smelting processes for reclamation. Materials retrieved from recovery, recycling, and smelting processes are Gold, Silver, Copper, Platinum, Nickel, Lead and Aluminum. These metals may be reused as raw material for future computer manufacturing. Waste from smelting processes should be complied with regulations before landfilling or incinerating.

Components in the Y group are tested to assure their capability and quality. If these components do not meet the requirements, they are treated like other components in the X group. If the result of testing is satisfactory, the product will be refurbished, reused, upgraded, washed and painted for future use. Components are reassembled with other parts and other components to remanufacture personal computers. The refurbished and reassembled computers are then resold to the consumer.

Summary

This chapter reviewed the research and results obtained from interviews. The data gathered from the interviews conducted answered the following goals:

1. The arrangement, management, and awareness according to the legislation from the European Union and the United States.
2. The Extended Producer Responsibility (EPR) program regarding computer manufacturing
3. The disposal of electrical and electronic waste programs such as takeback program, recycling, reuse and recovery program, and other methods of disposal of electrical and electronic waste.

Four process maps were created. These process maps included (1) Redesign Alternatives, (2) Risk management plan, (3) End-of-life management, and (4) Disposition of personal computer. These process maps answered objectives of this study.

CHAPTER V: DISCUSSION

This chapter provides the purpose of the study, the methods and procedures used in this study, the major findings, conclusions and the recommendations related to this study.

Purpose of the Study

The purpose of the study was to develop the risk management program to address the disposal of waste from computers and computer components and to assist Thai companies in complying with the WEEE and RoSH directives.

The objectives of this study were:

1. To identify best practices to address waste from electrical and electronic equipment.
2. To identify redesign alternatives.
3. To develop a risk management plan to address the disposal of electrical and electronic waste to comply with the WEEE and RoSH legislation from European Union.

Methods and Procedures

The methods and procedures included a review of literature pertaining to WEEE and RoHS directives. Semi-unstructured interviews were conducted with two companies that manufacture electrical and electronic equipment. The data gathered from the literature review and the interviews were analyzed in the following areas:

1. The arrangement, management, and awareness according to the legislation from European Union and the United States.

2. The Extended Producer Responsibility (EPR) program regarding computer manufacturing.
3. The disposal of electrical and electronic waste program such as takeback program, recycling, reuse and recovery program, and other disposals of electrical and electronic waste program.

Four process maps were created. These process maps included (1) redesign alternatives, (2) risk management plan, (3) end-of-life management, and (4) disposition of personal computer. These process maps address the objectives of this study. The "Process Map 1" describes the major activities and tasks for redesign alternatives. The "Process Map 1" provides steps served as a model for new product designs. The "Process Map 2" describes the risk management plan to address disposal of electrical and electronic waste to comply with the WEEE and RoHS legislation from European Union and other regulations. The "Process Map 3" describes the end-of-life management to address disposal of electrical and electronic waste. The "Process Map 4" describes the risk management plan for disposition of personal computers.

Major Findings

1. Two safety professionals from Company ABC and XYZ were knowledgeable with regard to hazardous waste regulations involving electronic waste and believed electrical and electronic equipment manufacturers should be responsible for waste generated.
2. Company ABC raised the awareness within the company of the need for new hardware products to meet the requirements of European Union (EU) directives by implementing a Design for the Environment (DFTE) system for several years.

3. Company XYZ considered WEEE and RoHS directives in their product development cycle. Life Cycle Management (LCM) and Design for Environment (DFE) were two tools that the company used to maintain a market in both existing products and new products.
4. Company ABC has policies and procedures to deal with the end-of-life product and also established processes for proper disposition of electrical and electronic waste. Company ABC also had a recovery, recycling, and reuse program to meet WEEE and RoHS directive requirement.
5. Eco-design, Life cycle management (LCM), and design for environment (DFE) were system approaches for a product design to achieve and maintain compliance with regulation. Each of these system approaches had an environmental aspect.
6. Recycling, reuse, recovery, remanufacturing, and takeback program were processes that helped promoting compliance to WEEE and RoHS directives.

Conclusions

1. The WEEE and RoHS directives had directly affected the electrical and electronic equipment manufacturing industry in Thailand. The current Thai regulations do not legislate the disposal of waste electrical and electronic equipment. In addition, the regulation did not require that producers assume responsibilities for all costs involved in the disposal of these wastes.
2. There were no specific programs to take back the end-of-life product and no effective procedure for recovery, reuse or to recycle the product following the requirement of the European Union directives. Many electrical and electronic equipment-manufacturing companies in Thailand did not prepare to comply with

the WEEE and RoHS legislation. Consequently, this would not allow them to continue to export electrical and electronic equipment to the EU and US.

3. Interviews showed that both companies have raised the awareness within the company of the need for new hardware products to meet the requirement of European Union (EU) directives known as RoHS and WEEE. However, both companies have not implemented a takeback program to take back the end-of-life products. One company currently has recycling, reuse, recovery program to promote compliance to European Union (EU) directives, while another company is exploring the alternatives of starting a program to deal with the electrical and electronic waste.
4. The end-of-life management to address the disposal of electrical and electronic waste include (1) environmental aspect and compliance with WEEE and RoHS directives, (2) defect and waste collection and product take back program, (3) classification and separation of end-of-life products, (4) product repair, reuse, and refurbished processes, (5) disassembly and recycling processes, (6) resale, incineration, and landfilling processes.
5. A risk management plan was a summary of the proposed risk management approaches. These approaches covered the overall activities used to identify, analyze, manage, control, measure, and finance risk. A risk management plan defined the risk goals and objectives, resources, responsibilities, and documentations required for risk management activities. In addition, a risk management plan contains basic program elements including (1) management leadership and employee involvement, (2) hazardous prevention and control, (3)

training program, (4) standard implementation, (5) measurement, evaluation, and corrective action (6) commending compliance and correcting deficiencies.

Recommendations Related to this Study

1. In order to achieve a sustainable solution to the electronic waste problem in Thailand, legislation must change the way business operates. On the other hand, legislation must require producers to be responsible for takeback and management of their products. Current legislation should comply with the European Union (EU) or follow legislation in other countries such as the United States, Sweden or Denmark.
2. Government and other related organization such as the Federation of Thai Industries (FTI) and Ministry of Commerce Organization should promote extended producer responsibility and join with the European Union to set up a process, make networking, and handle expenses involved in complying with WEEE and RoHS directives.
3. Local government representatives should coorporate with electrical and electronic equipment manufacturing companies to take back the end-of-life product and encourage product recovery, reuse, recycle and remanufacturing program.
4. Thai government should develop regulations to prevent exportation of electrical and electronic equipment waste from other countries.
5. Redesign alternatives such as Design for the Environment (DFTE), Life Cycle Analysis (LCA), Eco Design, and ISO 14000 should become a requirement for new product development in order to reduce waste, improve resource management and comply with WEEE and RoHS directives.

6. Improve consumer perception regarding issue related to managing electrical and electronic waste. This could be accomplished by providing education to inform consumer about opportunities for waste prevention in the recovery, reuse and recycling of electrical and electronic products.
7. Electrical and electronic equipment manufacturing companies should develop and encourage risk management plan to provide a framework for managing risk regarding the disposal of electrical and electronic waste, and to meet the WEEE and RoHS requirement.

Recommendations for Further Study

1. A study could be done on waste from electrical and electronic equipment besides the electronic waste from computer.
2. In order to solve the problem regarding electrical and electronic waste in Thailand, a study could be conducted from the electrical and electronic equipment manufacturing companies in Thailand, rather than in the United States.
3. A study could be conducted to determine if product redesign alternatives are effective long term solutions regarding performance, reliability and cost benefit in order to reduce waste, and improve resource management
4. A study could be conducted to measure and evaluate recovery, recycle, remanufacturing, and takeback program performance, in order to provide performance tracking and feedback in developing and improving the risk management planning process.
5. Besides safety professionals, a study could be conducted from upper management regarding issue related to managing electrical and electronic waste.

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APPENDIX A

DIRECTIVE 2002/96/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 27 January 2003
on waste electrical and electronic equipment (WEEE)

ANNEX II

Selective treatment for materials and components of waste electrical and electronic equipment in accordance with Article 6(1)

1. As a minimum the following substances, preparations and components have to be removed from any separately
collected WEEE:

- polychlorinated biphenyls (PCB) containing capacitors in accordance with Council Directive 96/59/EC of 16
- September 1996 on the disposal of polychlorinated biphenyls and polychlorinated terphenyls (PCB/PCT) (1),
- mercury containing components, such as switches or backlighting lamps,
- batteries,
- printed circuit boards of mobile phones generally, and of other devices if the surface of the printed circuit board
- is greater than 10 square centimetres,
- toner cartridges, liquid and pasty, as well as colour toner,
- plastic containing brominated flame retardants,
- asbestos waste and components which contain asbestos,
- cathode ray tubes,
- chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC) or hydrofluorocarbons (HFC), hydrocarbons (HC),
- gas discharge lamps,
- liquid crystal displays (together with their casing where appropriate) of a surface greater than 100 square centimeters and all those back-lighted with gas discharge lamps,
- external electric cables,

- components containing refractory ceramic fibres as described in Commission Directive 97/69/EC of 5 December 1997 adapting to technical progress Council Directive 67/548/EEC relating to the classification, packaging and labelling of dangerous substances (2),
- components containing radioactive substances with the exception of components that are below the exemption thresholds set in Article 3 of and Annex I to Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation (3),
- electrolyte capacitors containing substances of concern (height > 25 mm, diameter > 25 mm or proportionately similar volume)

These substances, preparations and components shall be disposed of or recovered in compliance with Article 4 of Council Directive 75/442/EEC.

2. The following components of WEEE that is separately collected have to be treated as indicated:

- cathode ray tubes: The fluorescent coating has to be removed,
- equipment containing gases that are ozone depleting or have a global warming potential (GWP) above 15, such as those contained in foams and refrigeration circuits: the gases must be properly extracted and properly treated. Ozone-depleting gases must be treated in accordance with Regulation (EC) No 2037/2000 of the European Parliament and of the Council of 29 June 2000 on substances that deplete the ozone layer (4).
- gas discharge lamps: The mercury shall be removed.

3. Taking into account environmental considerations and the desirability of reuse and recycling, paragraphs 1 and 2 shall be applied in such a way that environmentally-sound reuse and recycling of components or whole appliances is not hindered.

4. Within the procedure referred to in Article 14(2), the Commission shall evaluate as a matter of priority whether the

entries regarding:

- printed circuit boards for mobile phones, and
- liquid crystal displays are to be amended.

APPENDIX B

DIRECTIVE 2002/96/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 27 January 2003
on waste electrical and electronic equipment (WEEE)

ANNEX IA

Categories of electrical and electronic equipment covered by this Directive

1. Large household appliances
2. Small household appliances
3. IT and telecommunications equipment
4. Consumer equipment
5. Lighting equipment
6. Electrical and electronic tools (with the exception of large-scale stationary industrial tools)
7. Toys, leisure and sports equipment
8. Medical devices (with the exception of all implanted and infected products)
9. Monitoring and control instruments
10. Automatic dispensers